Wind Speed	3D Sonic anemomete r/ RM Young 81000	m/s	0-60 m/s	0.01 m/s	2 m abl, 4, 16 m agl, 0- 10 m from berm	160 Hz sampling/ 16 Hz averaging	30 min & 24 h	75% of 10 d each quarter
Wind Direction	3D Sonic anemomete r/ RM Young 81000	Degrees	0 o -360 o	0.1o	2 m abl, 4, 16 m agl, 0- 10 m from berm	160 Hz sampling/ 16 Hz averaging	30 min & 24 h	75% of 10 d each quarter
Measure ment	Method/ Instrument	Reporting Units	Required Operating range	MDL	Locations	Minimum sample frequency	Final Data-Aggre gation	Completen ess
3D Turbulen ce wind compon	3D Sonic anemomete r/ RM Young 81000	m/s	0-40 m/s	0.01 m/s	2 m abl, 4, 16 m agl, 10 m from berm	160 Hz sampling/ 16 Hz ave.	30 min	75% of 10 d each quarter
Tempera ture Variabilit y	3D Sonic anemomete r/ RM Young 81000	oC	-50 to +50oC	0.01oC	2 m abl, 4, 16 m agl, 10 m from berm	160 Hz sampling/ 16 Hz ave.	30 min	75% of 10 d each quarter

Quality Assurance Project Plan[1,2]

for the

National Air Emissions Monitoring Study (Open Source Emissions Component)

Sonic Anemometer Measurements.

Turbulent wind components (u′, v′, w′) are derived from the measured instantaneous orthogonal wind components (u, v, w) according to:

$$u' = U - u$$
$$v' = V - v \qquad \text{(Equation 7.1)}$$
$$w' = W - w$$

where u, v, and w are the time-averaged mean wind components in the northerly, easterly, and upwards directions. Wind speed along the axis of the emission plume will be calculated as a resultant over the period of measurement. The orthogonal components of wind (u, v, w) and virtual temperature (T_v) will be measured using RM Young 81000 sonic anemometers following the Standard Operating Procedure for the Measurement of Wind with the RM Young Model 81000 3-Dimensional Sonic Anemometer (SOP W2). Mean wind speed and wind direction will be calculated for 2-s measurement intervals at 2, 4, and 16 m agl heights to match the scan of five sequential TDLAS PIC measurements (section 7.2.1) for RPM plume reconstructions (Section 7.2.8). Turbulence (u′, v′, w′) and deviations in virtual temperature (T_v' where T_v'=instantaneous measured T_v – period-averaged T_v) will be derived from 30-min averaging periods at 2-m height abl at the lagoons and basin and 3-m height agl at the corral to match the UV-DOAS PIC measurements (Section 7.2.2) for bLS plume emissions calculations (section 7.2.5).

The desired accuracies and resolution of the sonic anemometer sensors are shown in Table 7.4. Also shown in the table are measurement resolutions and DQIs. Measurement resolutions are attained by the selection of measurement instruments. Measurement accuracy DQIs are met by calibration/verification and quality assurance audits. These are critical measurements.

Table 7.4. System accuracy, resolutions and DQIs for sonic anemometer measurements

Meteorological Parameter	Intercomparison Bias	Measurement Resolution	DQI
Orthogonal wind velocities U, V, and W	± 0.2 m/s	0.01 m/s	Within 0.2 m/s
Sonic temperature (T_v) calculated from V_o	±2 $_o$C[1]	0.02$_o$C	Within 2 $_o$C
Wind speed (horizontal)	± 0.2 m/s	0.01 m/s	Within 0.2 m/s
Wind direction (azimuth)	± 5 degrees	1 degree	N/A (computation from orthogonal

1: Sonic temperatures (T_v) will not be utilized in the project but is a measureable quantity to determine sensor performance. T_v' will be used to compute the Monin Obukov Length (*L*).

SOP W2. 2006. Measurement of Wind with the RM Young Model 81000 3-Dimensional Sonic Anemometer. Standard Operating Procedure W2. Purdue Ag Air Quality Lab/Purdue Applied Meteorology Lab.

RM Young. 2005. Manual for Model 81000 ultrasonic anemometer, Rev C031405. R.M. Young Co., Traverse City, MI. 9p.

<u>Wind Speed and Wind Direction Sensor (sonic anemometer)</u>: The locations of the wind sensors differ by type of measurement location; lagoon/ basin or corral. According to the World Meteorological Organization (WMO), the standard height for wind instruments over level, open terrain is 10 m above the ground. All lagoon/ basin measurement locations will have sensors at 2

m above berm level (abl) and 4 m and 16 m abl to provide wind profile information for the RPM emission measurements (described later) (SOP U5). Wind sensors will be 0 to 10 m from the edge of the berm at the lagoon and basin sites, more than 10 times the fan diameter away from building exhaust fans for mean wind measurements associated with the RPM emissions model (for 4 ft diameter fans, 40 ft) and 30 times the fan diameter away from the building exhaust fans for turbulence measurements associated with the bLS emissions model (for 4 ft diameter fans, 120 ft). Preferably, wind measurements will be made downwind of the lagoon or basin (based on prevailing wind direction). In general, the lagoon berms of the study locations are less than 1 m high. Consequently the distance from the anemometers to an obstruction will be at least 10 times the difference in height of the sensor and the nearest obstruction. The close proximity of the sensors to the measurement plane of the TDLAS beam paths is desired to reduce RPM emissions calculation error (RPM method described later). A 3D sonic anemometer will be securely mounted on the top of a 2-m mast and a 15-m corner tower. One additional 3D sonic anemometer will be mounted on a corner tower on a boom projecting at least two tower diameters away from the tower at 4-m height. This boom will be in a direction that provides the least wind distortion due to the tower structure for the most important wind direction or the prevailing wind direction. In this study, the wind speed and direction sensors will be combined using the 3D sonic anemometers. This is a critical project measurement.

Wind sensors will be at least 100 m from the edge of the feedlot at the corral sites to minimize roughness changes associated with the corral, providing a fetch of at least 10 times the height of the nearest obstruction. The anemometers will be securely mounted at the top of 2-m masts within 10 m of TDLAS paths along the sides of the corral.

In general, the quality of sonic anemometer turbulence measurements can only be assessed by side by side comparisons. Wind tunnel calibration (which is NIST traceable and provided by the manufacturer) provides only an evaluation of the mean wind and not the turbulent components and the turbulence in a wind tunnel is not sufficient to evaluate the response of the sonic anemometer to turbulence. Therefore all performance audits of sonic anemometers will rely on intercomparisons (Table 16.1). The three-dimensional sonic anemometers will be inter-compared with three NIST-traceable unused sensors (termed a triad) at the Purdue Weather Station open field facility every six months. Details concerning the intercomparison are documented in SOP W2.

In general, the quality of sonic anemometer turbulence measurements can only be assessed by side by side comparisons. Wind tunnel calibration (which is NIST traceable and provided by the manufacturer) provides only an evaluation of the mean wind and not the turbulent components and the turbulence in a wind tunnel is not sufficient to evaluate the response of the sonic anemometer to turbulence

Table A4. Measurement Quality Objectives- Parameters: Wind speed and direction (Model 81000 RM Young ultrasonic anemometer).

Requirement	Frequency	Acceptance criteria	Referenc	Information/ Action
Standard reporting units	All data	Speed: m/s Direction: deg.		

Shelter temperature	Daily	-50 - +50$_{o}$C	Manufacturer manual	Instrument mounted un-enclosed in the ambient environment
Equipment -3D sonic anemomet	Purchase specification	Speed: ±0.2 m/s + 5 % observed Direction: ±5 degrees	USEPA 454/R-99-005	

Table A19. Measurement Quality Objectives- Parameters: 3D turbulence components (Model 81000 RM Young ultrasonic anemometer)

Requirement	Frequency	Acceptance criteria	Reference	Information/ Action
Standard reporting units	All data	m/s		
Shelter temperature	daily	-50 - +50$_{o}$C	Manufacturer spec.	Sensor is exposed to ambient weather conditions
Equipment -3D sonic anemomet	Purchase spec.	U,V,W =0.2 m/s	Manufacturer spec.	
Detection	Purchase spec.	W, V, W: 0.01 m/s	Manufacturer spec.	
Completeness 5 min data	10 d within quarter	75%		No remediation possible Sampling will occur for approx. 21 d to assure 75% of 10 d in each quarter
Calibration Intercomparison with two other used sensors Intercomparison with unused sensor	On receipt Beginning/end of meas. period or 20d, whichever comes first. Every 6 mos.	Deviation in value from mean of three sensors of 0.2 m/s	SOP W2	Return to manufacturer for repair or replacement
Performance evaluation 1) spikes 2) obstructions 3) stationarity 4) homogeneity 5) spectral turbulence structure	 30 min 5 min 5 min 15 min daily	1) If spike <100 values/30 min, substitution with mean value 2) Internally flagged 3) invalidated if diff. betw. 5 min and 30 min values >30% 4) theoretical and derived values differ by >30%, data invalidate 5) Numerous tests	Foken and Wichura (1996) SOP W2	1)Data flagged as spiked 2) Data already flagged 3 and 4)Data flagged invalid 5)Data flagged suspect
Precision		0.05 m/s for 0 to 5 m/s, 1% of reading from 5 to 30 m/s, 3% of reading from 30 to 40 m/s.	Manufacturer spec.	This value is not measurable for turbulent flow. Value represents steady mean flow.
Accuracy		0.02 m/s	Manufacturer spec.	This value is not measurable for turbulent flow. Value represents steady mean flow.

Table A20. Measurement Quality Objectives- Parameters: Sonic Temperature (Model 81000 RM Young ultrasonic anemometer).

Requirement	Frequency	Acceptance criteria	Reference	Information/ Action
Standard reporting units	All data	$_{o}$C		
Shelter temperatur	Daily	-50 - +50$_{o}$C	Manufacturer specification	Sensor is exposed to ambient weather conditions
Equipment -3D sonic anemomet	Purchase specification	±2$_{o}$C	Manufacturer specification	
Detection	Purchase specification	0.01$_{o}$C	Manufacturer specification	
Completeness 5 min data	10 d within quarter	75%		No remediation possible Sampling will occur for approx. 21 d to assure 75% of 10 d in each quarter
Calibration	On receipt	±2$_{o}$C ±2$_{o}$C	Intercomparison with air temperature, SOP	Return to manufacturer for repair
Performance evaluation -Path obstruction -Spikes -mean value	 30 min 15 min 15 min	Values < 5 standard deviations of the mean Value < 3 $_{o}$C from hygrometer value	SOP W2	Data flagged
Precision			Manufacturer spec.	
Accuracy		±2$_{o}$C	Manufacturer specification	Sensor accuracy is low but not critical since deviations in temperature are of interest